

Follow-up of Schoolchildren in the Vicinity of a Coal-Fired Power Plant in Israel

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This study was carried out in the framework of a health monitoring system set up in the vicinity of a 1400 megawatt coal-fired power plant in Israel. Second- and fifth-grade schoolchildren were followed up every 3 years; they performed pulmonary function tests (PFT), and their parents filled out American Thoracic Society-National Heart and Lung Institute health questionnaires. Among the cohort of second graders (in 1983) living in the area expected to be most polluted, a significant increase in the prevalence of part of the respiratory symptoms (such as cough and sputum, wheezing with and without cold and wheezing accompanied by shortness of breath) was evident in 1986. The prevalence of asthma among fifth graders in this area doubled ($p = 0.0273$) compared with prevalence when they were second graders. Among the children from the older cohort (fifth graders in 1983) living in this community, a similar although milder trend could be observed, especially in regard to an increased prevalence of asthma in 1986 compared with 1983 (13.9% versus 8.1%). Annual increases in PFT in the four groups of children (boys and girls from both cohorts) were found to be higher in the community expected to be polluted (especially in the younger cohort) compared with the two other communities. The discrepancy between the increased prevalence of respiratory symptoms and diseases and the higher annual increase in PFT among children from the expected more polluted community may be partly attributable to differential annual increase in height and to different distribution of background variables (such as socioeconomic status, passive smoking, heating, and respiratory diseases among parents) in the three communities.

Introduction

The first coal-fired power plant in Israel is located on the seacoast in a semi-rural region midway between Tel-Aviv and Haifa. The plant consists of four 350 megawatt units. In 1981 the units were gradually put into operation until the summer of 1984, at which time all were operating. The permit to build and operate this power plant was given provided that three monitoring systems, environmental, agricultural, and long-term health monitoring, be set up near the plant. An advisory epidemiological committee decided on a health monitoring system, which included four health surveys: mortality survey, requests for health services, schoolchildren health survey, and an adult panel study (1). This paper deals with the results of the third round of tests carried out among schoolchildren. The comparison of the data from the two earlier rounds are discussed elsewhere (2).

Subjects and Methods

A follow-up is regularly conducted in three cohorts of schoolchildren, i.e., second-, fifth-, and eighth-grade pupils

living in three communities with different expected levels of air pollution located within 19 km of the power plant (Fig. 1). Baseline data for this study were gathered in 1980, before the first unit was put into operation. The second data set was gathered in 1983 when two units of the plant were operating, and the third set was gathered in spring 1986 when all units had operated for at least 2 years. The health questionnaire used in this survey is a translated version of the American Thoracic Society-National Heart and Lung Institute (ATS-NHLI) self-administered questionnaire (3), to be completed by the children's parents. The questionnaires were distributed to the children by the school nurses who also collected them after they were completed. After receiving these questionnaires, the survey technician conducted pulmonary function tests (PFT) in the participating schools using a portable, digital spirometer (Minato AS-1000). The PFT parameters obtained were forced vital capacity (FVC), forced expiratory volume in 1 sec ($FEV_{1.0}$), $FEV_{1.0}/FVC$, and peak expiratory flow (PEF).

The pupils performed the test standing and repeated the maneuver at least three times until two similar tests (within 10%) were obtained. The best test (highest $FVC + FEV_{1.0}$) was chosen. In each round the same technician carried out the PFT in all the participating schools. The school nurses weighed the children and measured their height. All tests were done between April and June during the morning hours. Statistical analysis was carried out using the SPSS program (4). Prevalences of background variables, respiratory symptoms, and diseases among

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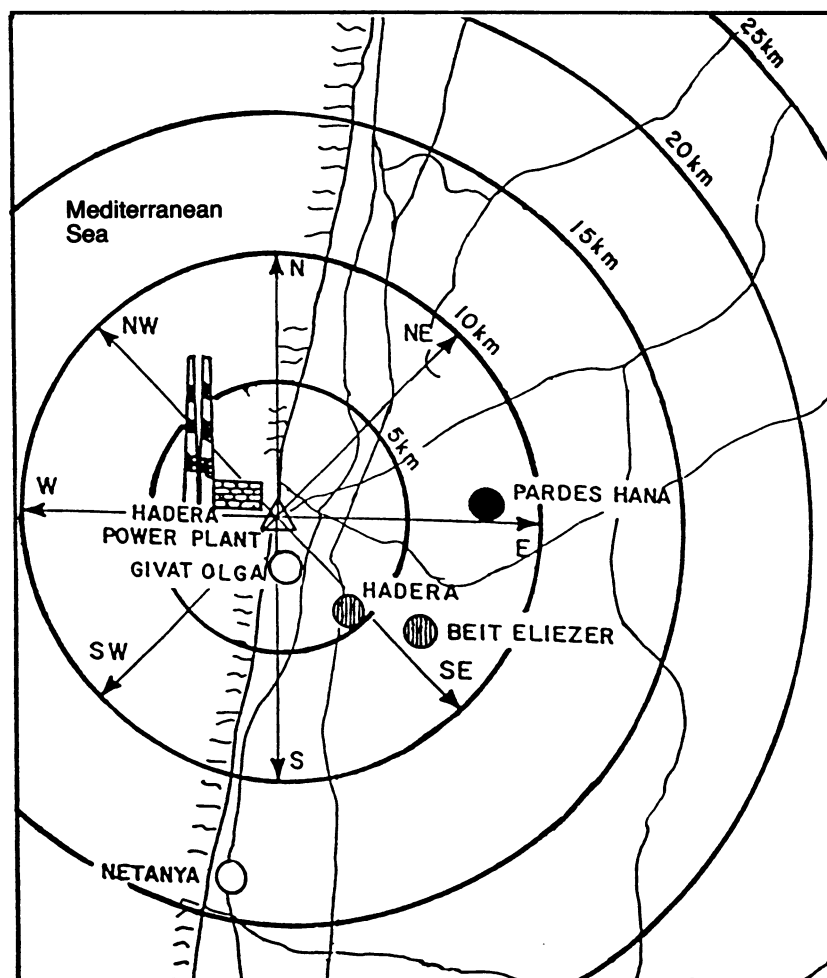


FIGURE 1. Site of the power plant and the communities studied. (Open circles) expected low pollution; (hatched circles) expected medium pollution; (filled circle) expected high pollution.

children from the three communities with expected different levels of air pollution were analyzed by means of chi-square test for examination of independence between two variables. The annual changes in pulmonary function test (PFT) among boys and girls in the studied cohorts living in the three communities were analyzed using one-way analysis of variance. Regression of annual changes in PFT on annual changes in height was carried out.

Results

In Table 1 a summary of the schoolchildren population by grade and year of examination is presented. Of the second and fifth graders in 1983, 915 and 885, respectively, were reexamined in 1986. No difference in the prevalence of background

variables (e.g., socioeconomic status, parental smoking) could be observed between followed-up children and those who were not reexamined. Changes over time were analyzed only among children who were reexamined.

In the younger cohort, e.g., second graders in 1983, the prevalence of most respiratory symptoms became lower when children grew up in the community expected to be least polluted. In the expected medium-polluted community, part of the symptoms became more prevalent and part of them less common. In the community expected to be polluted most, symptoms became more prevalent; the change over time was statistically significant ($p = 0.0012$) for cough and sputum (Table 2). As regards the temporal changes in the prevalence of respiratory diseases for children in the younger cohort, almost all of them became less common in the community expected to be low polluted, whereas the changes over time in the other communities were mixed, part of them became less and part of them more common.

It is interesting to stress the significant rise in the prevalence of asthma in the community expected to be polluted (Table 3). For the older cohort-fifth graders in 1983, the temporal changes

Table 1. Study population by year and age.

Year of study	Second graders	Fifth graders	Eighth graders
1980	991	999	736
1983	1165	1090	698
1986	1128	1157	993

Table 2. Prevalence of respiratory symptoms (percent) in the younger cohort (second graders in 1983) in the three communities by expected pollution.

Respiratory symptom	Low pollution (Givat Olga)			Medium pollution (Hadera)			High pollution (Pardes Hana)		
	1983	1986	p-value	1983	1986	p-value	1983	1986	p-value
Cough with cold	55.7 (140)*	46.5 (127)	0.1649	36.9 (474)	30.9 (447)	0.0619	45.0 (220)	39.6 (227)	0.2940
Cough without cold	14.5 (138)	8.7 (127)	0.1991	7.8 (472)	8.7 (448)	0.7209	10.0 (220)	7.1 (225)	0.3573
Sputum with cold	27.3 (132)	22.2 (126)	0.4268	17.8 (466)	19.4 (443)	0.5925	15.1 (218)	9.5 (221)	0.2847
Sputum without cold	6.1 (131)	4.0 (125)	0.6293	2.8 (464)	2.9 (442)	1.0000	1.9 (214)	4.5 (221)	0.1945
Cough with sputum	16.1 (124)	9.6 (125)	0.1771	8.7 (460)	5.8 (432)	0.1232	4.3 (211)	13.8 (210)	0.0012*
Wheezing with cold	19.2 (120)	18.5 (124)	1.0000	11.8 (423)	9.0 (432)	0.2206	10.0 (200)	15.1 (205)	0.1605
Wheezing without cold	12.9 (101)	10.0 (120)	0.6468	7.8 (386)	5.8 (415)	0.3267	4.7 (170)	7.3 (193)	0.4267
Wheezing with shortness of breath	13.8 (130)	14.5 (124)	1.0000	12.1 (456)	14.5 (440)	0.3188	13.2 (212)	17.1 (217)	0.3294

*Number of children in parentheses.

*p < 0.05.

Table 3. Prevalence of respiratory diseases (percent) in the younger cohort (second graders in 1983) in the three communities by expected pollution.

Respiratory disease	Low pollution (Givat Olga)			Medium pollution (Hadera)			High pollution (Pardes Hana)		
	1983	1986	p-value	1983	1986	p-value	1983	1986	p-value
Lung disease last 3 years	16.9 (136)*	8.8 (127)	0.0783	6.8 (468)	3.6 (443)	0.0424*	6.1 (212)	6.0 (208)	1.0000
Lung disease with sputum	8.8 (125)	6.3 (126)	0.6204	5.6 (445)	2.0 (444)	0.0089*	3.4 (204)	3.2 (219)	1.0000
Measles	26.2 (103)	18.0 (111)	0.1999	12.3 (367)	12.4 (355)	1.0000	9.4 (180)	11.5 (192)	0.6424
Sinus trouble	3.1 (97)	2.7 (110)	1.0000	2.4 (369)	4.7 (362)	0.1477	2.3 (176)	3.5 (188)	0.2158
Bronchitis	27.3 (110)	16.2 (111)	0.0673	20.5 (391)	19.3 (373)	0.7566	22.4 (196)	21.6 (194)	0.9456
Asthma	16.0 (106)	10.2 (108)	0.2861	11.1 (387)	11.9 (371)	0.8342	8.2 (183)	16.2 (191)	0.0273*
Pneumonia	31.0 (113)	27.0 (111)	0.6146	22.9 (402)	19.7 (371)	0.3173	13.4 (187)	17.4 (190)	0.3506
Ear infections	32.1 (109)	27.4 (106)	0.5401	32.9 (401)	30.1 (382)	0.4414	32.8 (189)	30.0 (190)	0.6330
Tonsilitis	5.3 (132)	4.2 (119)	0.9107	8.3 (459)	9.0 (424)	0.8090	3.3 (215)	3.2 (219)	1.0000
Allergy	12.3 (130)	13.3 (120)	0.9577	14.5 (455)	15.1 (418)	0.8886	12.1 (215)	17.0 (212)	0.1949

*Number of children in parentheses.

*p < 0.05.

in the prevalence of respiratory symptoms in the three communities were somewhat different. Most respiratory symptoms became less common in the community expected to be medium polluted, while in the other two communities the trend was mixed (Table 4). As regards the temporal changes in the prevalence of respiratory diseases among the children of the older cohort, most of them tended to be less common in the communities expected to be low and medium polluted, while in the community expected to be polluted, part of them, as asthma, became more common (Table 5).

As can be seen from Table 6, the annual increase in FVC, FEV_{1,0}, and PEF was higher in the older cohort compared with the younger one in the three studied communities. The annual

Table 4. Prevalence of respiratory symptoms (percent) in the older cohort (fifth graders in 1983) in the three communities by expected pollution.

Respiratory symptom	Low pollution (Givat Olga)			Medium pollution (Hadera)			High pollution (Pardes Hana)		
	1983	1986	p-value	1983	1986	p-value	1983	1986	p-value
Cough with cold	48.5 (136)*	42.5 (113)	0.4085	35.0 (440)	35.0 (411)	1.0000	41.2 (182)	37.4 (190)	0.5144
Cough without cold	12.6 (135)	12.5 (112)	1.0000	10.4 (441)	7.5 (412)	0.1736	9.3 (183)	9.0 (189)	1.0000
Sputum with cold	16.5 (133)	20.0 (110)	0.5964	19.3 (441)	21.1 (412)	0.5588	21.7 (180)	21.1 (185)	0.9930
Sputum without cold	8.2 (134)	9.1 (110)	0.9880	4.8 (442)	4.1 (411)	0.7880	5.6 (178)	7.0 (185)	0.7373
Cough with sputum	9.5 (126)	4.7 (107)	0.2436	8.0 (436)	5.1 (411)	0.1165	7.5 (173)	9.7 (176)	0.6005
Wheezing with cold	12.9 (124)	11.9 (109)	0.9789	11.6 (415)	7.6 (408)	0.0697	10.3 (175)	10.6 (179)	1.0000
Wheezing without cold	4.4 (113)	4.6 (108)	1.0000	7.4 (390)	5.3 (399)	0.2686	5.7 (141)	7.0 (171)	0.8025
Wheezing with shortness of breath	14.0 (129)	13.9 (108)	1.0000	10.5 (429)	9.0 (410)	0.5498	11.4 (176)	13.2 (182)	0.7157

*Number of children in parentheses.

Table 5. Prevalence of respiratory diseases (percent) in the older cohort (fifth graders in 1983) in the three communities by expected pollution.

Respiratory disease	Low pollution (Givat Olga)			Medium pollution (Hadera)			High pollution (Pardes Hana)		
	1983	1986	p-value	1983	1986	p-value	1983	1986	p-value
Lung disease last 3 years	8.3 (132)*	4.6 (109)	0.3667	7.7 (441)	4.6 (413)	0.0818	7.3 (178)	4.9 (184)	0.4591
Lung disease with sputum	5.9 (119)	2.7 (110)	0.3989	5.6 (430)	1.9 (412)	0.0099*	3.7 (164)	2.2 (183)	0.6190
Measles	28.8 (118)	29.2 (96)	1.0000	16.6 (373)	14.3 (370)	0.4447	27.7 (148)	16.5 (139)	0.0334*
Sinus trouble	0.9 (110)	1.1 (93)	1.0000	4.1 (366)	3.2 (371)	0.6686	2.7 (146)	6.4 (141)	0.2302
Bronchitis	17.2 (116)	12.6 (95)	0.4618	18.9 (380)	16.6 (373)	0.4600	12.8 (149)	14.8 (149)	0.7366
Asthma	8.0 (113)	10.6 (94)	0.6733	10.0 (369)	8.6 (370)	0.6048	8.1 (149)	13.9 (151)	0.1511
Pneumonia	19.1 (115)	17.9 (95)	0.9594	17.5 (382)	14.8 (379)	0.3488	15.8 (152)	16.0 (150)	1.0000
Ear infections	28.6 (105)	26.7 (101)	0.8893	29.1 (371)	26.6 (380)	0.4886	37.8 (143)	36.4 (151)	0.9071
Tonsilitis	6.0 (133)	3.8 (105)	0.6357	8.8 (433)	8.7 (402)	1.0000	10.3 (174)	8.1 (172)	0.6014
Allergy	12.3 (130)	15.9 (107)	0.5460	14.0 (430)	18.7 (401)	0.0783	13.8 (167)	10.1 (168)	0.3884

*Number of children in parentheses.

*p < 0.05.

increase in FVC and FEV_{1,0} in the four subgroups was highest in the community expected to be most polluted. For boys and girls from the younger cohort, the lowest annual increase in FVC and in FEV_{1,0} was observed in the community expected to be least polluted, while for the older cohort the lowest annual increase was observed in the community expected to be medium polluted. The annual increase in PEF in the younger cohort did not differ significantly between the three communities. The differences in the older cohort were statistically significant only among boys; the highest annual increase in PEF characterized boys from the community expected to be least polluted.

The annual increase in height was highest in the community expected to be most polluted and lowest in the community expected to be medium polluted in the four studied subgroups (boys

Table 6. Annual increase in FVC, FEV_{1,0}, PEF, and height for boys and girls of both cohorts in the three communities.

	Boys				Girls			
	Low	Medium	High	p-value	Low	Medium	High	p-value
Young cohort (second-grade pupils in 1983)								
Height, cm/year	5.06 (0.75)*	4.89 (1.06)	5.48 (1.19)	< 0.0001	5.52 (1.13)	5.32 (1.34)	6.03 (1.59)	< 0.0001
FVC, L/year	0.167 (0.077)	0.179 (0.095)	0.209 (0.074)	0.0016	0.116 (0.372)	0.169 (0.088)	0.220 (0.079)	0.0001
FEV _{1,0} , L/year	0.132 (0.058)	0.138 (0.089)	0.174 (0.057)	< 0.0001	0.112 (0.371)	0.155 (0.086)	0.202 (0.070)	0.0009
PEF, L/sec-year	0.379 (0.245)	0.390 (0.241)	0.386 (0.216)	0.9352	0.402 (0.654)	0.420 (0.246)	0.448 (0.248)	0.6283
Old cohort (fifth-grade pupils in 1983)								
Height, cm/year	6.46 (1.48)	5.81 (1.70)	6.48 (1.54)	0.0004	5.14 (1.41)	4.86 (1.38)	5.15 (1.71)	0.0001
FVC, L/year	0.326 (0.156)	0.261 (0.143)	0.339 (0.141)	< 0.0001	0.254 (0.103)	0.220 (0.172)	0.277 (0.111)	0.0013
FEV _{1,0} , L/year	0.270 (0.131)	0.212 (0.136)	0.294 (0.122)	< 0.0001	0.227 (0.091)	0.203 (0.177)	0.262 (0.092)	0.0012
PEF, L/sec-year	0.553 (0.310)	0.455 (0.372)	0.536 (0.291)	0.0414	0.407 (0.330)	0.466 (0.370)	0.498 (0.266)	0.1748

*SD in parentheses.

and girls from the two cohorts). By means of regression analysis of annual changes in PFT on annual changes in height, we tried to explain the temporal changes in PFT in the three communities. In three subgroups of children the annual changes in height explained only 4 to 8% of the variance in PFT in the three communities. Only among boys from the older cohort could the annual changes in height explain about 40% of the variance of annual changes in PFT.

The association of towns for environmental protection operates a network of 12 air monitoring stations in the radius of 25 km from the power plant. The monitoring stations are fully automatic and measure the following parameters: SO₂, NO, NO₂, and total NO_x; part of them also measure total hydrocarbons, O₃, CO, and TSP (total suspended particulate matter). Atmospheric data such as wind speed, wind direction, temperature, relative humidity, barometric pressure, solar radiation, and precipitation are also collected. The instruments are automatically calibrated, and the data sent by radio to the center of the

association of towns and fed into a computer that stores and analyzes them. As can be seen from Table 7, the range of monthly average concentrations for SO₂ are between 0 and 22 µg/m³. The highest monthly concentrations for SO₂ characterize the community expected to be medium polluted. CO is not regularly measured in Pardes-Hana, and for the other two communities measurements were available only for January to August 1985. Here again the values in the city of Hadera are considerable higher compared with the other community. As regards NO_x values they do not seem to vary considerably among the three communities.

Discussion

The community expected to be medium polluted, as a result of the operation of the power plant, is a city, while the other two communities are more rural. Air pollution levels measured in the vicinity of the power plant are extremely low. The highest

Table 7. Air pollution measurements in the vicinity of the power plant, January 1985–June 1986.

Month and year	Expected low pollution (Netanya)			Expected medium pollution (Hadera)			Expected high pollution (Pardes Hana)		
	SO ₂ , µg/m ³	CO, ppb	NO _x , ppb	SO ₂ , µg/m ³	CO, ppb	NO _x , ppb	SO ₂ , µg/m ³	CO, ppb	NO _x , ppb
January 1985	2.8	70	18	14.0	610	3	8.4	—	8
February 1985	5.6	90	15	11.2	340	7	8.4	—	8
March 1985	5.6	60	15	19.6	530	9	8.4	—	8
April 1985	8.4	120	22	22.4	550	12	5.6	—	8
May 1985	2.8	50	17	11.2	640	7	5.6	—	9
June 1985	2.8	20	10	5.6	280	6	2.8	—	8
July 1985	2.8	30	11	2.8	220	8	8.4	—	18
August 1985	2.8	60	13	5.6	110	10	8.4	—	21
September 1985	2.8	—	11	2.8	—	15	2.8	—	15
October 1985	5.6	—	13	5.6	—	19	5.6	—	17
November 1985	11.2	—	20	2.8	—	25	11.2	—	17
December 1985	11.2	—	20	11.2	—	22	8.4	—	17
January 1986	11.2	—	20	11.2	—	22	8.4	—	17
February 1986	5.6	—	17	8.4	—	26	5.6	—	18
March 1986	8.4	—	15	16.8	—	21	8.4	—	17
April 1986	5.6	—	13	8.4	—	22	8.4	—	18
May 1986	5.6	—	15	5.6	—	18	8.4	—	17
June 1986	2.8	—	13	5.6	—	16	5.6	—	19

monthly average concentrations for SO_2 and CO measured in Hadera, the community expected to be medium polluted, are apparently a result of urban pollution rather than a result of emissions from the power plant. It seems that the expectations of "low," "medium," and "high" pollution were not met.

The distribution of respiratory symptoms and diseases among children from three communities with different expected levels of pollution seems to be connected with several other factors (5) rather than with air pollution levels, which were very low in all three communities. The community expected to be least polluted is characterized by lowest socioeconomic status (by crowding index, lack of heating of houses, fathers' and mothers' education) in both cohorts. The prevalence of respiratory symptoms and most respiratory diseases among children of the younger cohort growing up in this community was, in 1983, much higher compared with the prevalence among children from the other two communities. In the older cohort this trend was less obvious. It seems that adverse health effects of low socioeconomic status diminish with age of exposed children. This fact partly explains the sharp decline in the prevalence of respiratory symptoms and diseases in the expected low-pollution community. Respiratory problems among parents of children growing up in the community expected to be most polluted became more prevalent in both cohorts. This could be a partial explanation of the rise in the prevalence of asthma and wheezing among their children.

The annual increase in FVC and in $\text{FEV}_{1,0}$ in the four subgroups (boys and girls from both cohorts) was highest in the community expected to be most polluted. Since the annual increase in height was also highest in this community, we made a regression analysis of annual changes in PFT on annual changes in height. Only among boys from the older cohort could the annual changes in height explain a relatively high proportion of the variance of annual changes in PFT in the three communities.

Still, a discrepancy between the rise in prevalence of most respiratory symptoms and diseases among children from the younger cohort (and to a certain extent from the older cohort) growing up in the community expected to be most polluted and the highest annual rise in FVC and $\text{FEV}_{1,0}$ among the same

children exists. This annual rise in PFT can only partly be explained by annual changes in height. The lowest annual increase in FVC and in $\text{FEV}_{1,0}$ among children from the younger cohort growing up in the community expected to be least polluted may be partly attributed to the lower socioeconomic status in this community, the effect of which diminishes with age. The lowest increase in FVC and in $\text{FEV}_{1,0}$ among children from the older cohort living in the community expected to be medium polluted may be partly attributed to the lowest rise in height among them and to a city effect in this community. In the analysis carried out in 1983 (2), the lowest increase in respiratory symptoms characterized the children growing up in the community expected to be most polluted. On the other hand, the rise in their PFT (FVC and $\text{FEV}_{1,0}$) as well as the increase in their height was lowest compared with the other two communities.

These are preliminary results of the third round of tests, carried out in 1986; further analysis of existing data as well as analysis of further data gathered in the fourth round in 1989 will perhaps lead to a better understanding of factors influencing the longitudinal trends in the studied cohorts in the three communities.

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